Re-assembling Hetch Hetchy

Water Supply Implications of Removing O'Shaughnessy Dam

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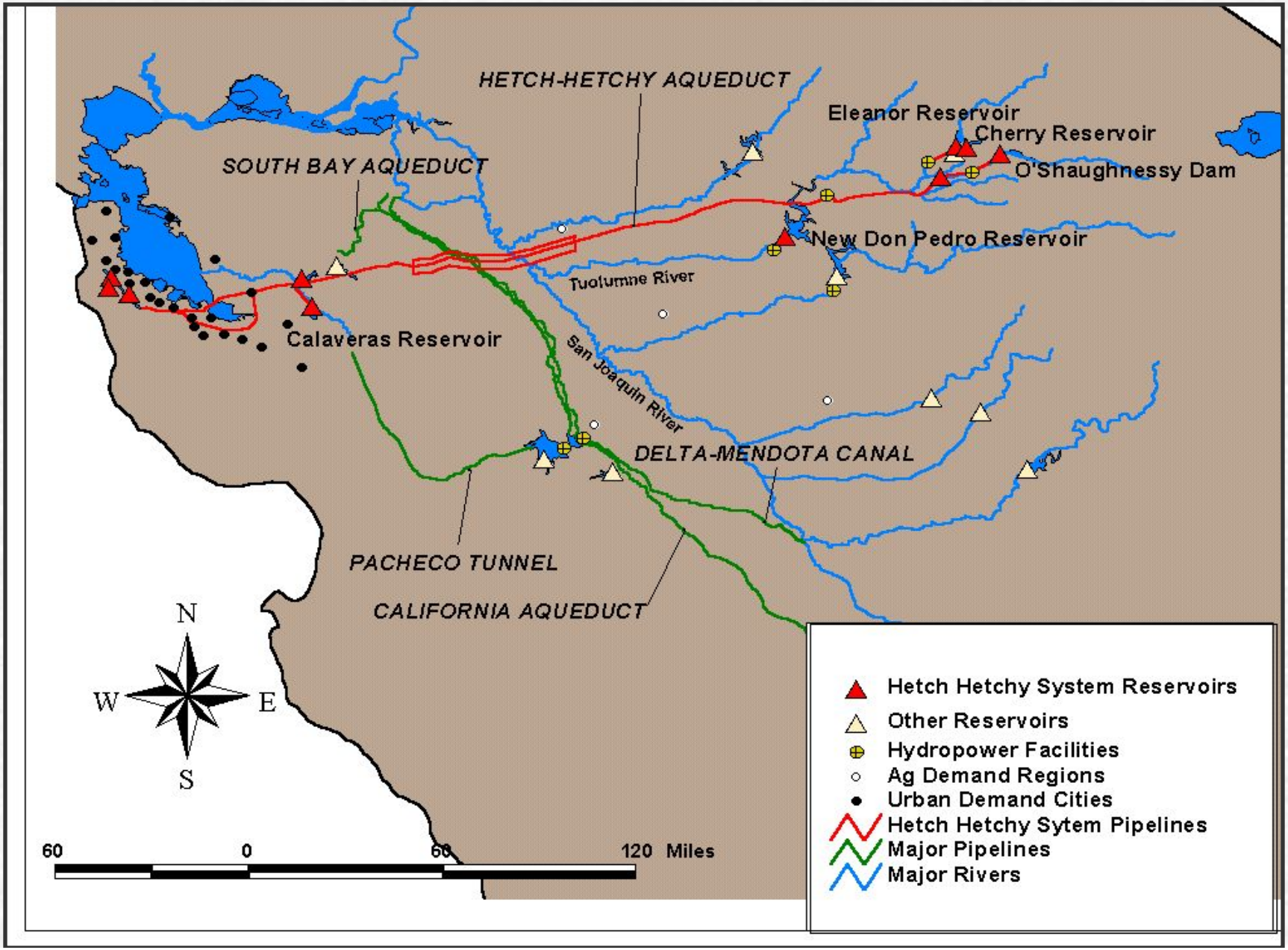
Questions

- If O'Shaughnessy Dam were removed, could existing water storage facilities supply the Hetch Hetchy System's service area with water?
- Would additional scarcity occur in other urban, agricultural, or environmental water demand areas in the region without O'Shaughnessy Dam?
- What hydropower revenues would be lost from removing O'Shaughnessy Dam?
- What water quality costs would be incurred from removing O'Shaughnessy Dam?

The Hetch Hetchy System



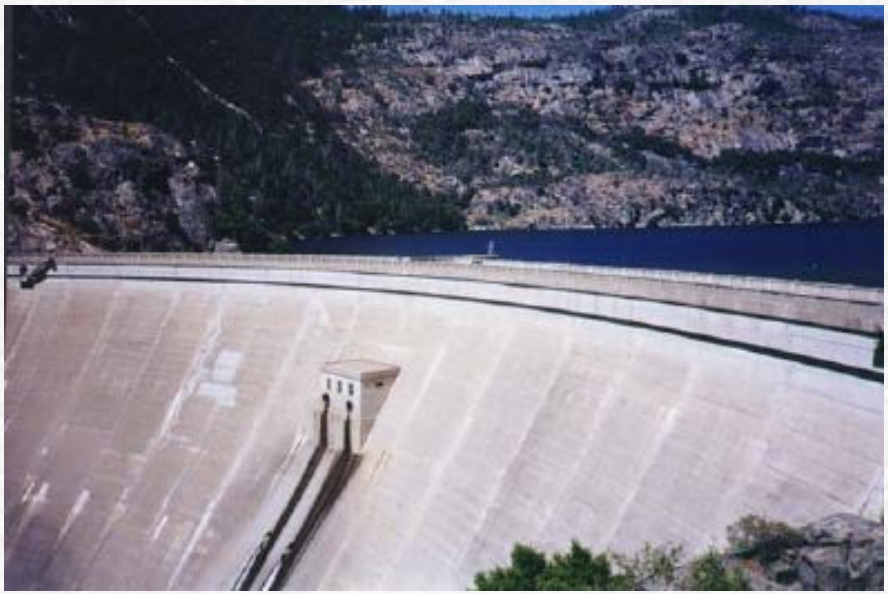
Reasons to restore Hetch Hetchy Valley

Hetch Hetchy Valley, 1908

- Water is scarce, but Yosemite Valley is also a scarce resource.
  - Restoring Hetch Hetchy Valley could open an area equal to Yosemite Valley to wildlife and recreation.
- Recreation and tourism benefits may exceed water storage and hydropower benefits of the reservoir.
- Ethical and aesthetic reasons - should a reservoir for San Francisco be in Yosemite National Park?

O’Shaughnessy Dam

- A Hetch Hetchy System component.
- About 25% of SFPUC’s storage in the Hetch Hetchy System, 14% of storage on the Tuolumne River.
- Provides no conveyance to San Francisco water users.
- Operated primarily for water supply and hydropower production.
  - Cherry and Eleanor storage operate solely for hydropower in most years.



Filtration Avoidance

- Currently, water from O'Shaughnessy Dam has filtration avoidance status.
  - This means the water is very pure and meets water quality standards.
  - Minimal water treatment needed (such as chlorine or chloramine as a disinfectant).
  - Very few systems in the US qualify for filtration avoidance.

Reservoir Capacities

in the Hetch Hetchy System

Hetch Hetchy System Storage	
Reservoir	Capacity (taf)
O'Shaughnessy*	360
Lake Eleanor	28
Cherry Lake	268
New Don Pedro	570**
San Antonio	50
Calaveras	97
Lower Crystal Springs	58
Pilarcitos	3
San Andreas	19
Total HH System Storage	**1,454**
Other Tuolumne River Storage	
New Don Pedro (MID & TID)	1,460
Total Basin Storage	
All Reservoirs	**2,914**

* Filtration Avoidance Permit

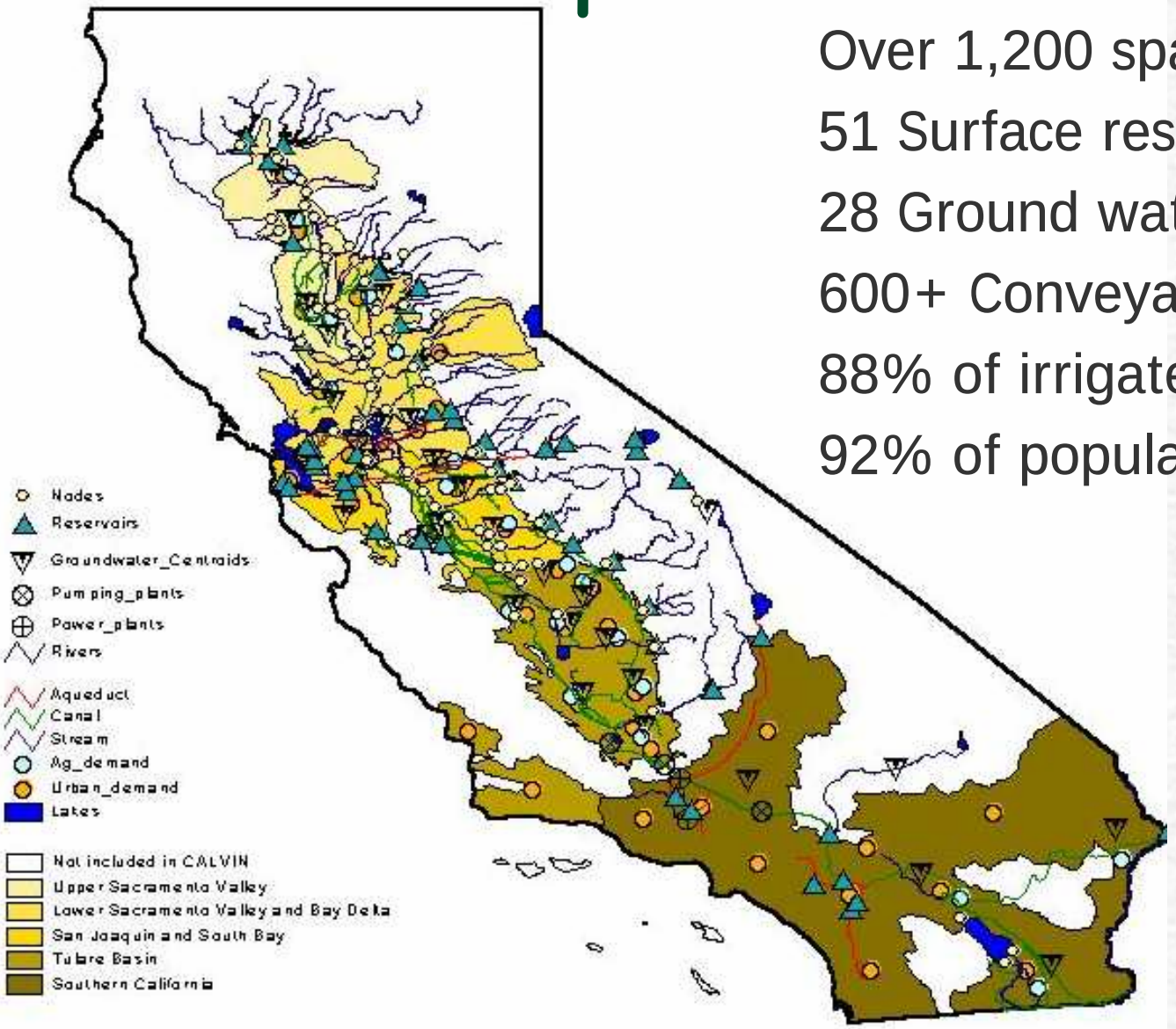
**Space owned by the city and county of San Francisco Total Storage in New Don Pedro Reservoir = 2,030

CALVIN: an economic-engineering optimization model

- Minimizes economic costs within constraints
  - Economic value functions for agricultural and urban uses
  - Operating costs: hydropower, water treatment, pumping, groundwater recharge
  - Flow constraints for environmental uses

- Prescribes operation over a 72-year historic hydrology
- Surface and groundwater systems
- Major hydropower facilities
- Year 2020 projected demands and infrastructure
- Hypothetical inter-tie links New Don Pedro Reservoir with Hetch Hetchy Aqueduct.

CALVIN's Spatial Coverage



Over 1,200 spatial elements

51 Surface reservoirs

28 Ground water reservoirs

600+ Conveyance Links

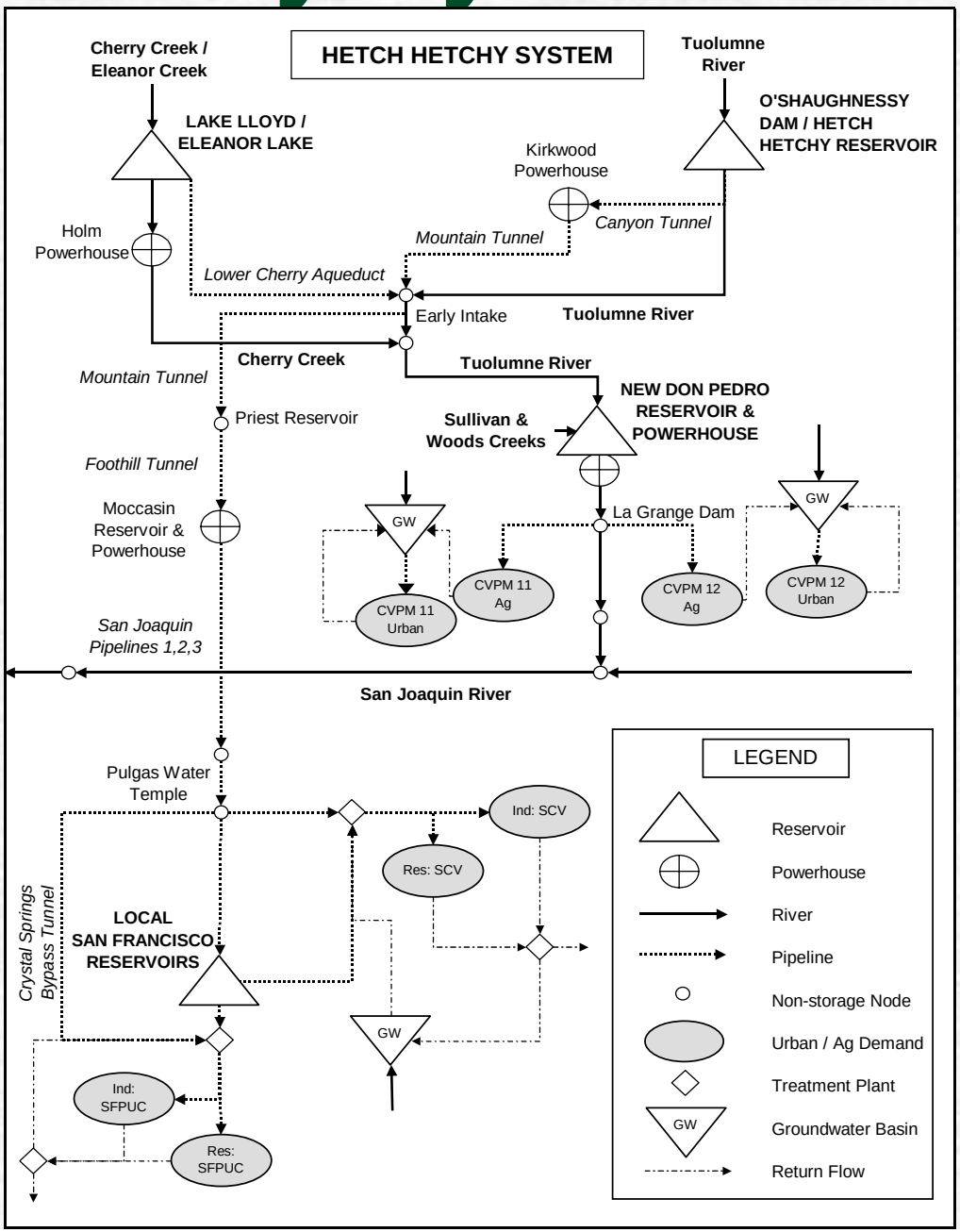
88% of irrigated acreage

92% of population

Management Options

- Surface reservoir operations
- Groundwater reservoir operations
- Water allocation (markets & exchanges)
- Urban conservation/use efficiencies
- Cropping changes and fallowing
- Agricultural water use efficiencies
- New technologies
    - Wastewater reuse
    - Seawater desalination

Hetch Hetchy System Schematic



Model Limitations

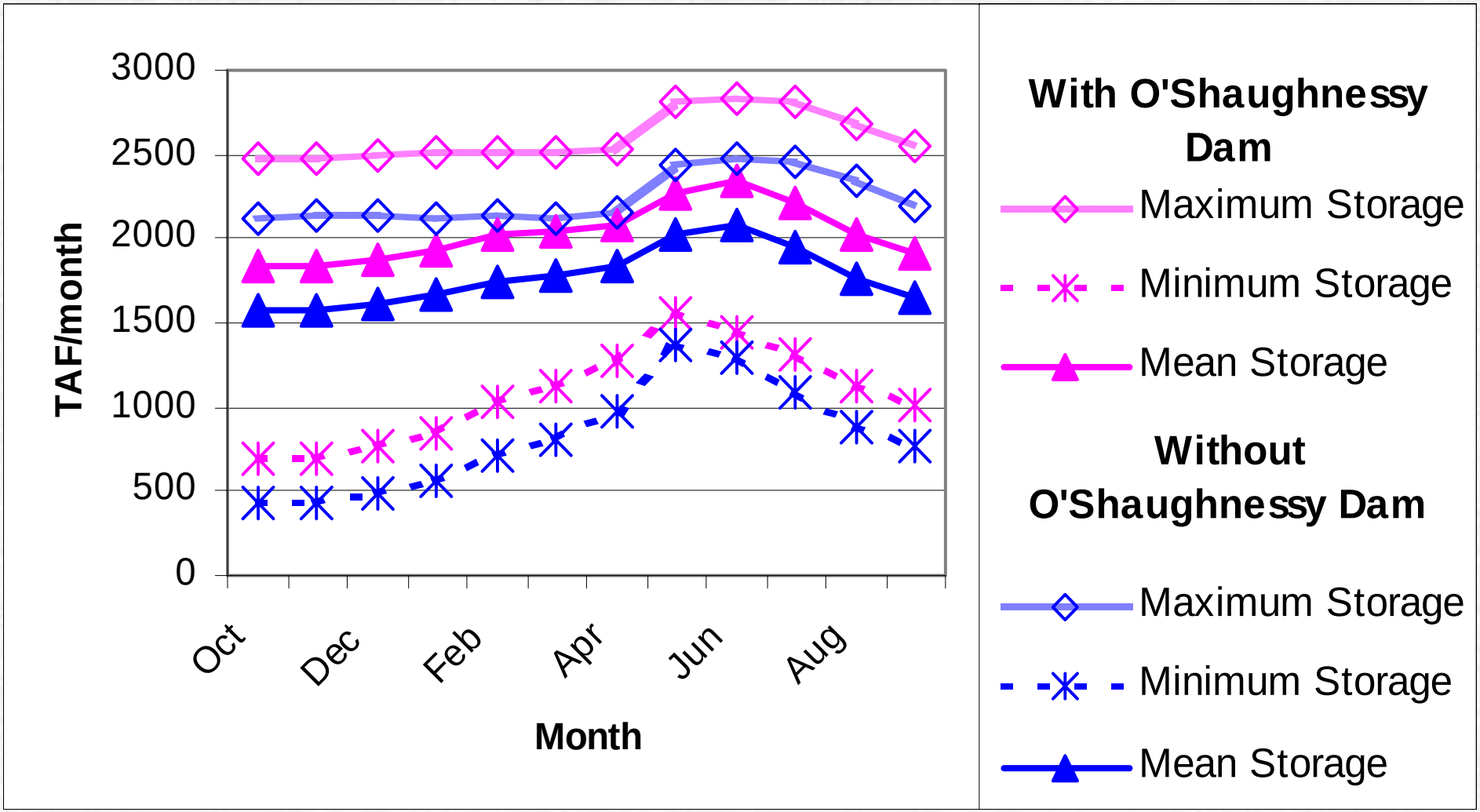
- Ignores political and institutional constraints
- No flood control or recreational benefits, but current flood storage rules are respected
- Simplified costs, water quality, hydrology
- Operates reservoirs aggressively with perfect foresight

Model runs

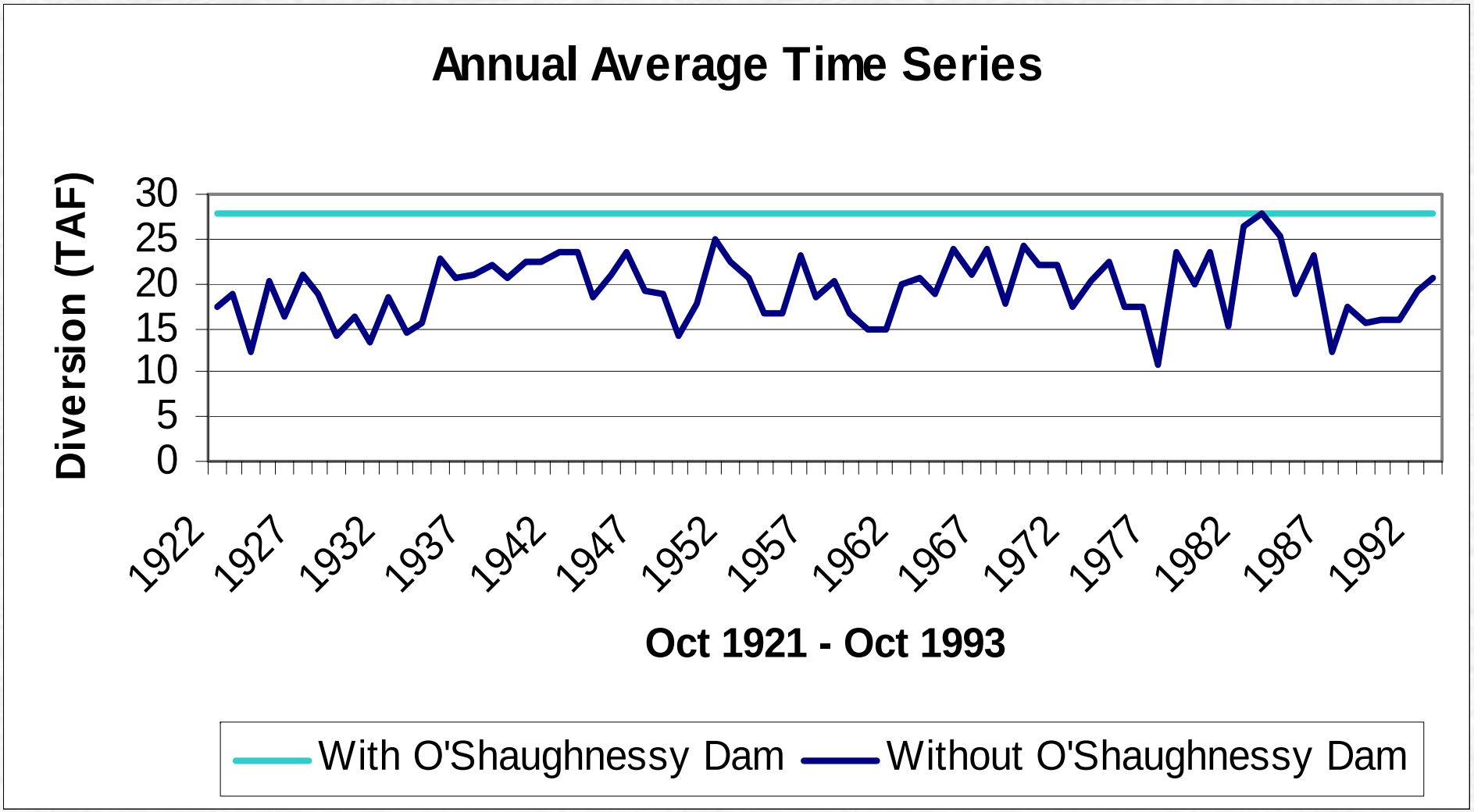
	Keep Filtration Avoidance	Lose Filtration Avoidance
Retain O'Shaughnessy Dam	2020 Base Case	2020
Remove O'Shaughnessy Dam and add New Don Pedro inter-tie	Scenario modeled, produced no new results	2020

- Model runs optimize South Bay / San Joaquin River area and include:
  - 13 surface water reservoirs, 5 GW basins, 7 major hydropower facilities
  - 6 urban demand regions, 4 agriculture regions
  - 2 wildlife refuges, minimum instream flows on 3 river reaches
- A hypothetical inter-tie links New Don Pedro and the Hetch Hetchy Aqueduct (for runs without O'Shaughnessy Dam).
- The base case run is constrained to current operating policies, all other runs are unconstrained.

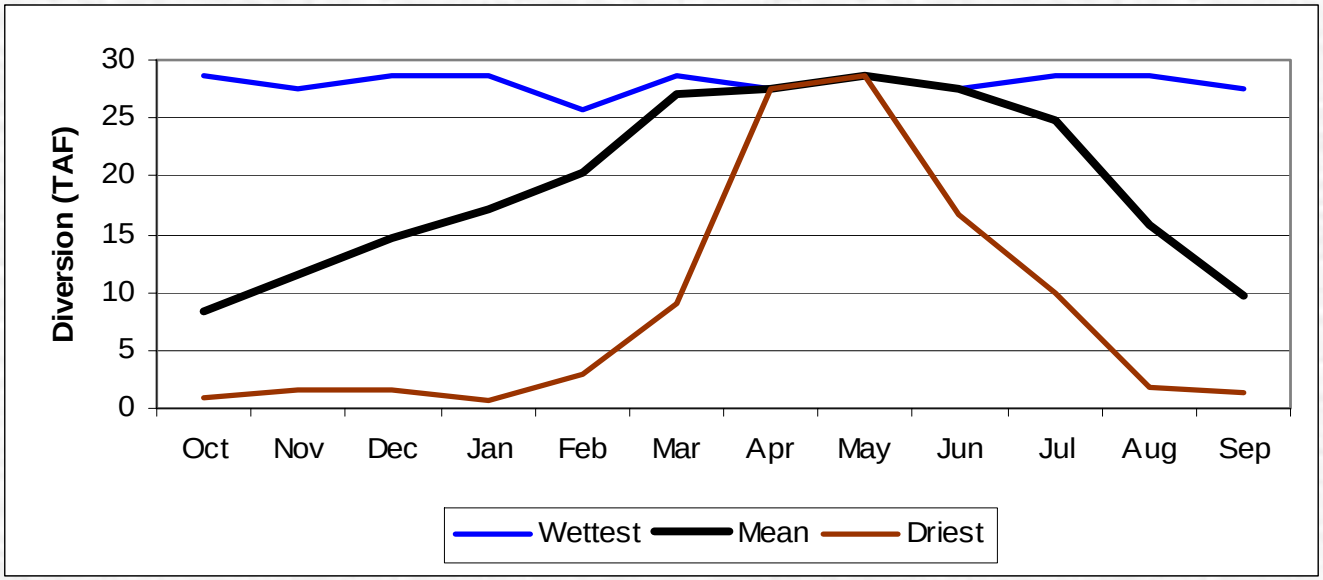
Hetch Hetchy System Water Storage with and without O'Shaughnessy Dam



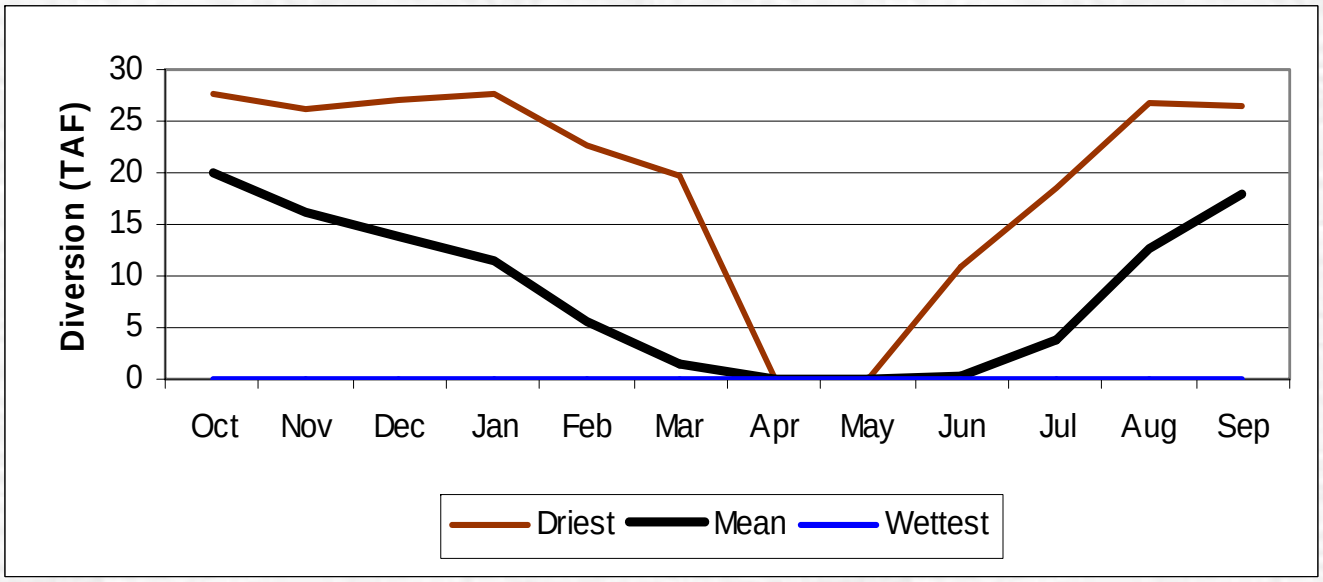
Hetch Hetchy Aqueduct upstream of New Don Pedro



Hetch Hetchy Aqueduct Flows



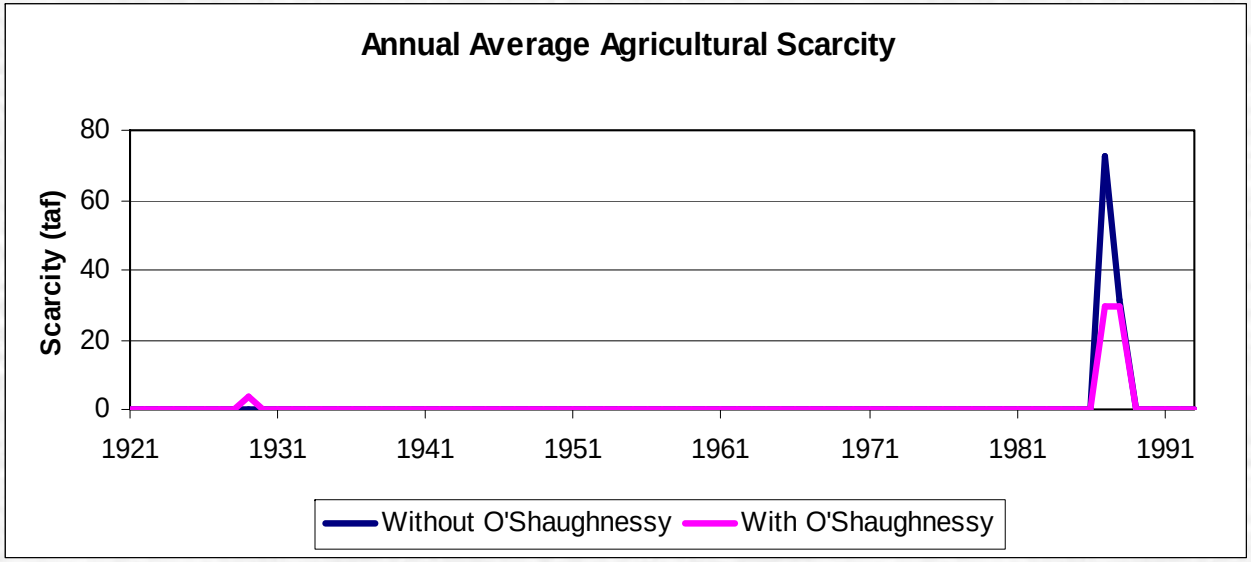
Seasonal Flow in Hetch Hetchy Aqueduct upstream of New Don Pedro



Flow through New Don Pedro Inter-tie

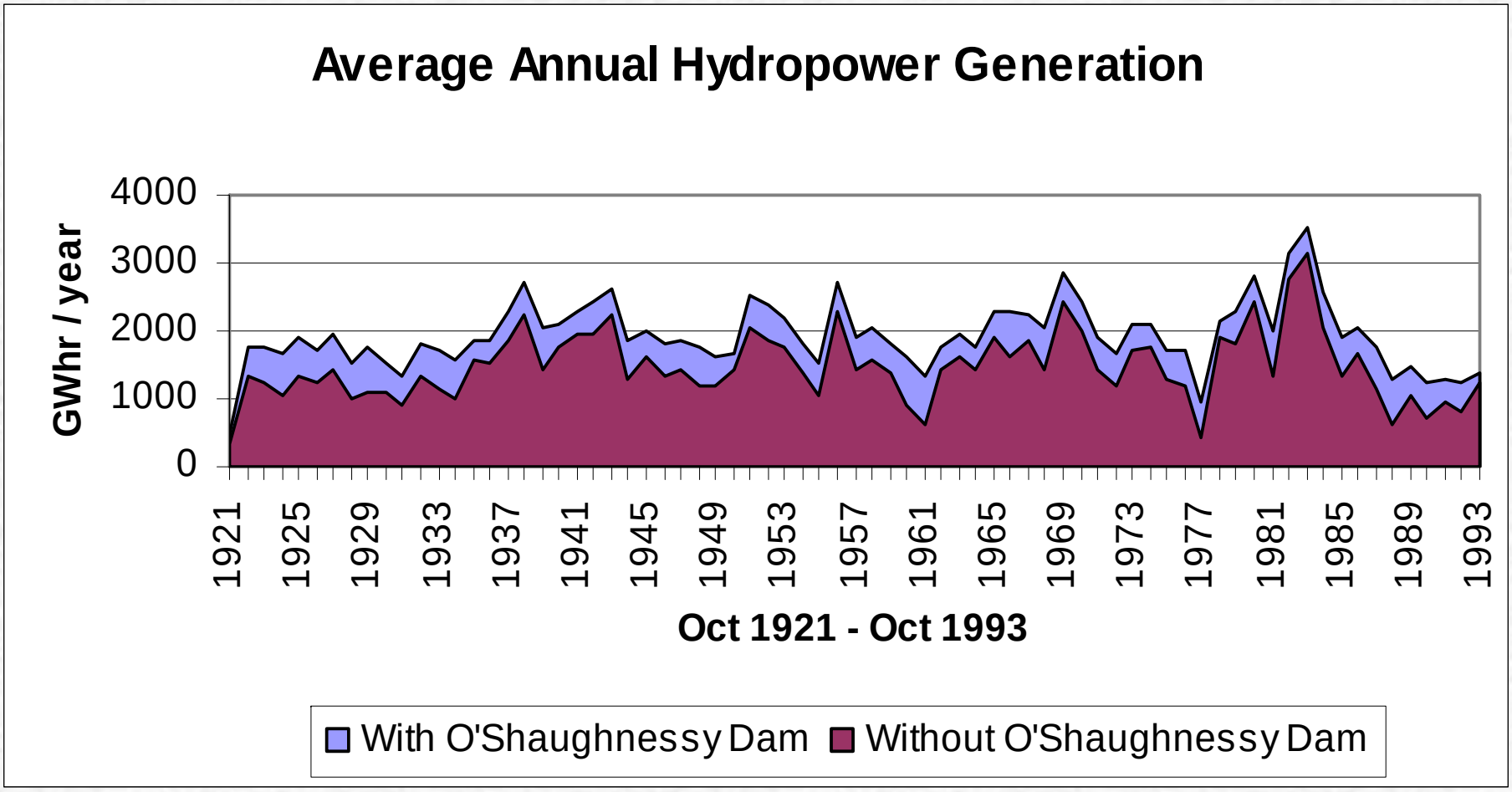
Water Scarcity

- No scarcity to urban areas.
- No scarcity to environmental demands.
- Small increase in scarcity to TID and MID (CVPM 11 & 12) without O'Shaughnessy Dam.
- No scarcity to other agricultural demands.



	With O'Shaughnessy Dam	Without O'Shaughnessy Dam
Average annual scarcity (taf)	0.85	1.42
Max annual scarcity (taf)	29.3	72.5
% years with scarcity	0.04	0.03
Average annual demand (taf)	5259	5259
Average annual delivery (taf)	5258	5257

Hetch Hetchy System Hydropower Generation



Average annual difference = 457 GWhr/yr
Average annual cost difference = $11,107,050

Water Treatment Changes

- Removing O'Shaughnessy Dam would prompt loss of regulatory filtration avoidance status, raising water treatment costs.
  - Construction costs, about $1-2 billion ($50-100 million/yr).
  - O&M costs, about $6 million/year.
- Filtration avoidance makes O'Shaughnessy Dam very valuable.
- Water quality would remain high.

Major Conclusions

- Removing O'Shaughnessy Dam need not substantially increase water scarcity.
  - Capture of considerable runoff could be possible at the damsite for much of most years
  - No effects outside the Tuolumne basin, if New Don Pedro Reservoir is connected directly with the Hetch Hetchy Aqueduct.
- Conveyance can sometimes substitute for water storage. (Intertie between New Don Pedro Reservoir and Hetch Hetchy Aqueduct)
- Loss of filtration avoidance, would be very costly.
- Removing O'Shaughnessy Dam reduces hydropower generation and revenues.
- Optimization modeling helps identify promising re-operations for water resource systems potentially undergoing restoration.

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Thesis available online:
http://cee.engr.ucdavis.edu/faculty/lund/students/SarahNullThesis.pdf

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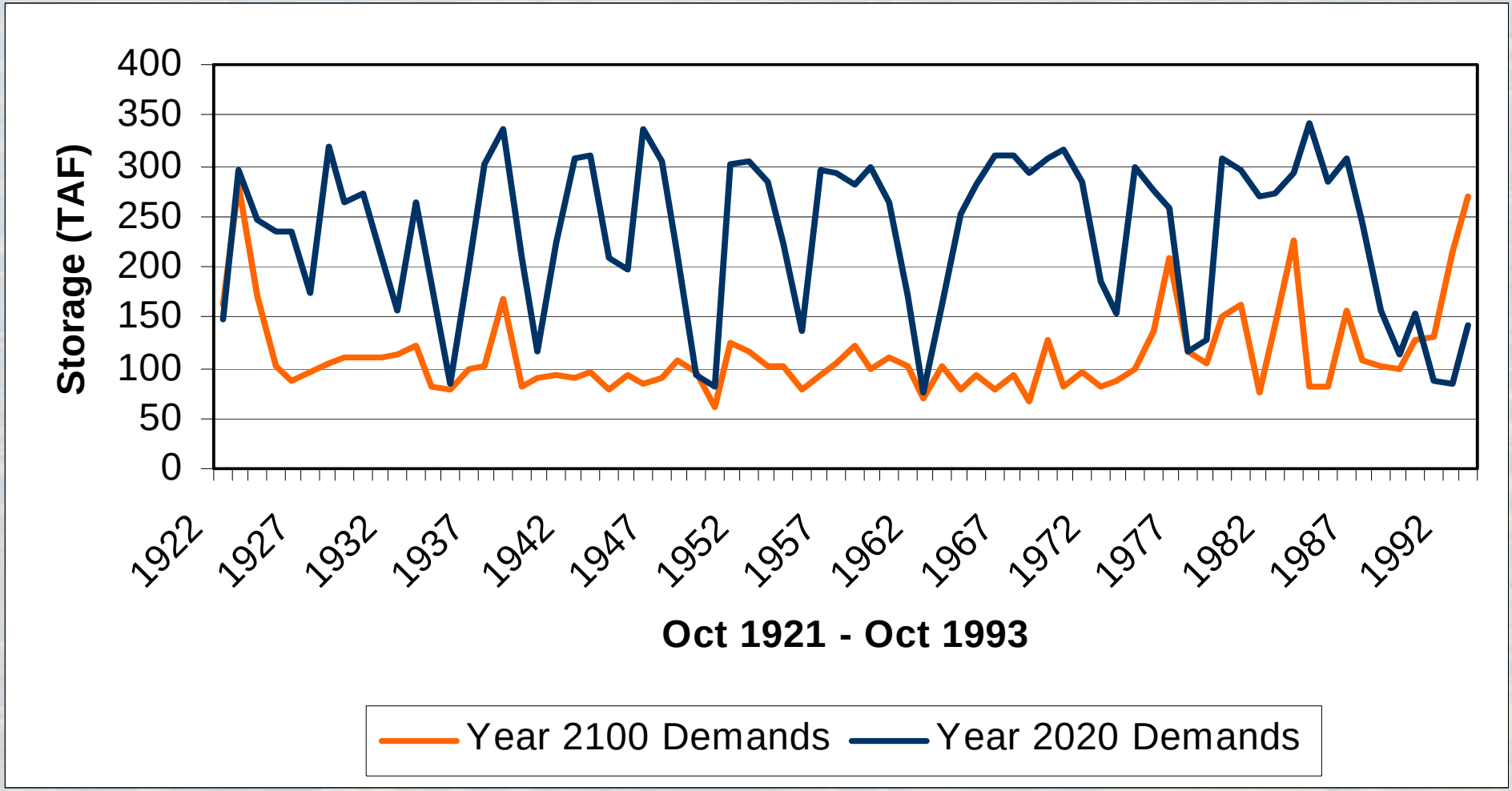
Year 2100 Model Runs

- How would the Hetch Hetchy System respond to much, much higher demand?
- Will removing O'Shaughnessy Dam lead to increasing problems in the future?

- Historical hydrology
- Network changes:
  - San Francisco and Santa Clara Valley demand regions were given unlimited access to seawater desalination at $1000/af
  - Urban wastewater recycling made available for up to 50% of return flows, also $1000/af
  - O&M water treatment costs were increased to represent the loss of filtration avoidance by the year 2100

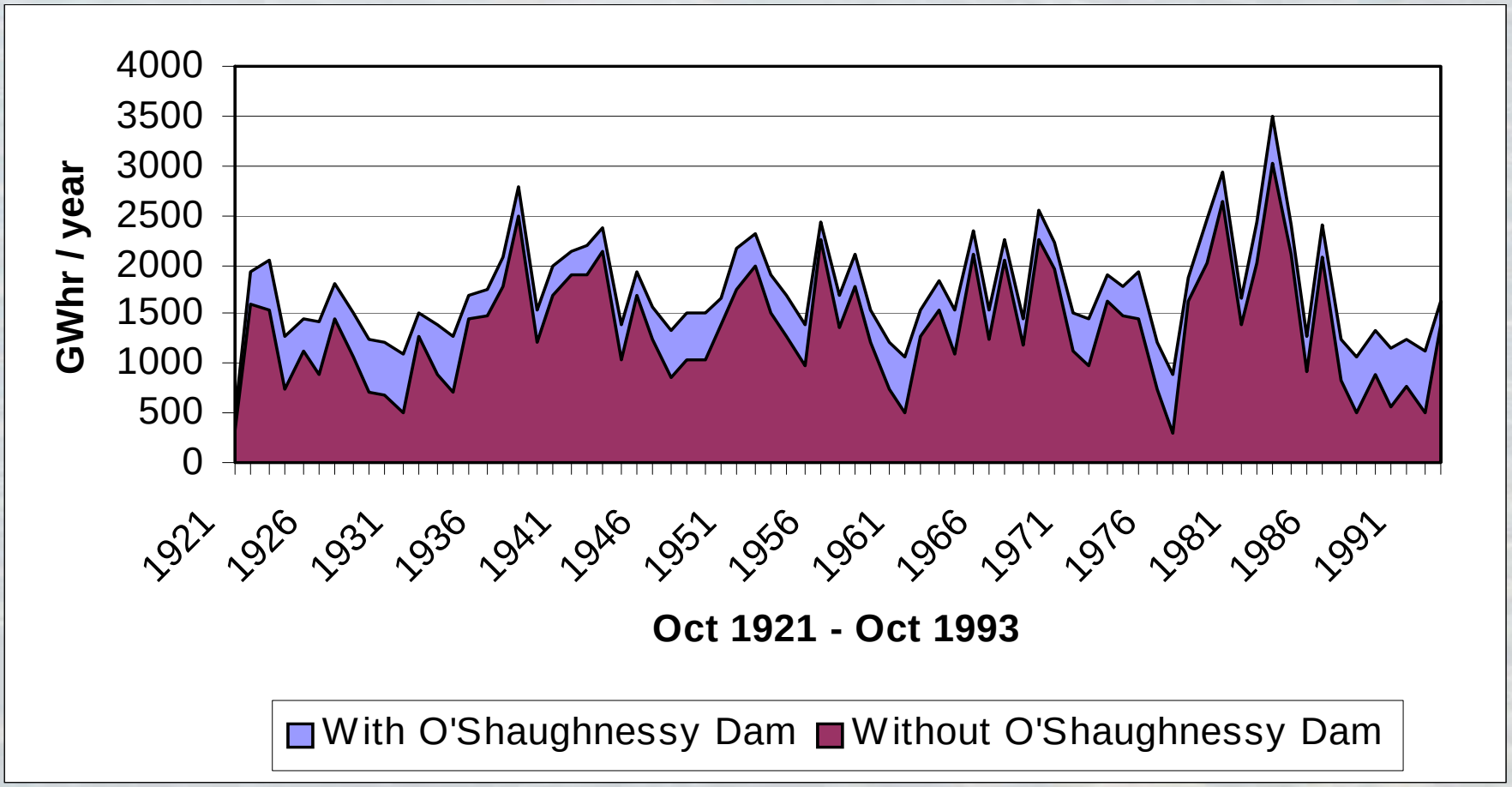
Average Annual Storage at O'Shaughnessy Dam with Year 2020 Demand and Year 2100



Average 2100 Deliveries, Scarcity, and Scarcity Cost

Urban Regions	With O'Shaughnessy Dam	Without O'Shaughnessy Dam
Average Deliveries (taf/yr)	1,948	1,948
Average Scarcity (taf/yr)	6	6
Average Scarcity Cost ($K/yr)	4,086	4,076
Agricultural Regions		
Average Deliveries (taf/yr)	4,506	4,509
Average Scarcity (taf/yr)	753	749
Average Scarcity Cost ($K/yr)	75,466	74,754

Average Annual Hetch Hetchy System Hydropower Generation with year 2100 Demand



Average annual cost difference of ~ $9.5 million
Average annual energy difference of ~ 378 GWhr

Conclusions

1) In year 2100, scarcity to agricultural regions is extensive. Removing O'Shaughnessy Dam does not increase urban or agricultural water scarcity.

2) There is a surplus of surface storage, but not enough water. Storage is not water.

3) Water is not stored over-season, it is quickly used to meet demand.

4) Water storage increases in groundwater basins.

5) The lower Hetch Hetchy Aqueduct remains at capacity regardless of the existence of O'Shaughnessy Dam (assuming a NDP inter-tie).

6) Substantial hydropower remains despite lower reservoir levels.

7) For 2100, an inter-tie with New Don Pedro Reservoir is more valuable than O'Shaughnessy Dam

Annual Average Urban Deliveries, Scarcity, and Scarcity Cost

Demand Area	Location	Base Case with O'Shaughnessy*	With O'Shaughnessy	Without O'Shaughnessy **
	Annual Average Urban Deliveries (taf/yr)	**1,424**	**1440**	**1440**
SFPUC	City and County of San Francisco, San Mateo County	232	238	238
SCV	Santa Clara Valley, Alameda County and Alameda Zone 7 Water Districts	646	656	656
CVPM 10 Urban	Madera, Merced, San Joaquin, and Stanislaus Counties	42	42	42
CVPM 11 Urban	San Joaquin and Stanislaus Counties	232	232	232
CVPM 12 Urban	Merced and Stanislaus Counties	109	109	109
CVPM 13 Urban	Madera and Merced Counties	162	162	162
	Total Urban Scarcity (taf/yr)	**16**	**0**	**0**
	Total Urban Scarcity Cost ($1,000/yr)	**15,290**	**0**	**0**

* Constrained to current operating policies

** Results do not change with loss of filtration avoidance

Annual Average Ag. Deliveries, Scarcity, and Scarcity Cost

Demand Area	Location	Base Case with O'Shaughnessy*	With O'Shaughnessy	Without O'Shaughnessy**
	Annual Average Ag. Deliveries (taf/yr)	**5259**	**5258**	**5257**
CVPM 10	Valley Floor west of San Joaquin R.	1698	1698	1698
CVPM 11	Eastern San Joaquin Valley above Tuolumne R.	867	866	866
CVPM 12	Eastern Valley Floor between San Joaquin R. and Tuolumne R.	803	803	802
CVPM 13	Eastern Valley Floor between San Joaquin R. and Merced R.	1891	1891	1891
	Annual Average Ag. Scarcity (taf/yr)	**0**	**1**	**1.5**
CVPM 10	Valley Floor west of San Joaquin R.	0	0	0
CVPM 11	Eastern San Joaquin Valley above Tuolumne R.	0	<1	<1
CVPM 12	Eastern Valley Floor between San Joaquin R. and Tuomune R.	0	0	<1
CVPM 13	Eastern Valley Floor between San Joaquin R. and Merced R.	0	0	0
	Annual Average Scarcity Cost ($1000/yr)	**0**	**5**	**11**
CVPM 10	Valley Floor west of San Joaquin R.	0	0	0
CVPM 11	Eastern San Joaquin Valley above Tuolumne R.	0	5	6
CVPM 12	Eastern Valley Floor between San Joaquin R. and Tuomune R.	0	0	5
CVPM 13	Eastern Valley Floor between San Joaquin R. and Merced R.	0	0	0

* Constrained to current operating policies

** Results do not change with loss of filtration avoidance